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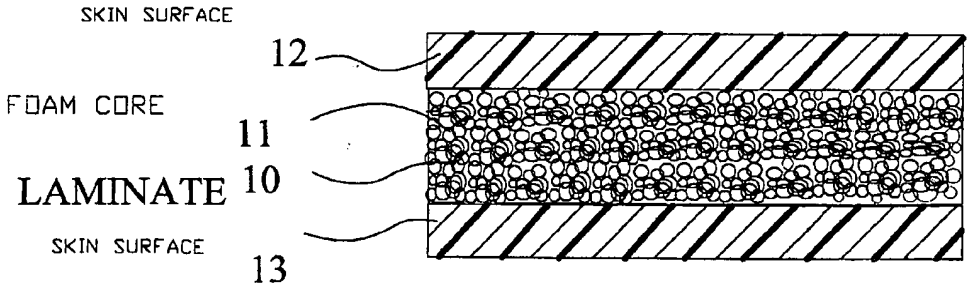
(54) Title: HDPE (HIGH DENSITY POLYETHYLENE) FOAM CORE LAMINATE STRUCTURE



(57) Abstract: This invention is a HDPE (High Density Polyethylene) Foam Core Laminate Structure with an HLMI-HDPE Surface. The laminate can be formed in sheets, tubes, and/or other shapes. It can be formed and/or thermoformed into structures such as reusable and disposable pallets and/or containers. The invention provides for the use of a laminate structure made with a HDPE foamed sheet as a core with one or two surfaces of a solid or foamed material. This patent gives preference for having one or more high molecular weight HDPE skin surfaces. High molecular weight HDPE gives high impact strength to the skin surface. For the core, a medium molecular weight HDPE with a melt index in the range of 0.2 to 0.4 g/10 min is used to help produce acceptable quality foam and provide the performance characteristics desired. For the skin surfaces, the preference is for the use of a high molecular weight, 10 to 12 g/10 min high load melt index HDPE with desired physical properties. Either or both of the skins can be solid or foamed. Either or both of the core and skin surfaces can be made with neat or crosslinked HDPE. For a pallet application the preferred thickness of the foam core can be from 0.100" to 1.0" thick, for preferably from 0.200" to 0.500" thick, and more preferably from 0.200" to 0.300" thick. The end use application and ease in processing; foaming and post laminating processing and/or thermoforming will predicate foam core thickness.

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HDPE (HIGH DENSITY POLYETHYLENE) FOAM CORE LAMINATE STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of prior U.S. Provisional Application No. 60/276,692, filed March 16, 2001; which is hereby incorporated by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention has been created without the sponsorship or funding of any federally sponsored research or development program.

BACKGROUND OF THE INVENTION

[0003] This invention relates to polymer foams, laminated structures, and artifacts or compositions made of the same. More particularly this invention relates to HDPE based polymer foams, preferably made with a medium molecular weight resin and laminated preferably with a skin or skins of high molecular weight HLMI-HDPE (High Load Melt Index-High Density Polypropylene) sheets of a high density foam or solid mass. Herein lies the novelty of this patent. Prior art has demonstrated use of solid high molecular weight HDPE in the use of construction of material handling devices such as pallets and totes. Though providing the structures with strength, the structures have been heavy and hence ergonomically less desirable. Attempts to foam the high molecular weight HDPE to provide weight reduction to the structures have been generally unsuccessful due to the limitations of the polymer. Only sight reduction in density has been demonstrated without any significant ergonometric improvement.

[0004] These and other difficulties experienced with the prior art systems have been obviated in a novel manner by the present invention.

[0005] It is, therefore, an outstanding object of the present invention to provide an improved foam core and skinned laminate structure.

[0006] It is a further object of the invention to provide a laminate which is capable of being manufactured of high quality and at a low cost, and which is capable of providing a long and useful life with a minimum of maintenance.

[0007] With the foregoing and other objects in view, which will appear as the description proceeds, the invention resides in the combination and arrangement of steps and the details of the composition hereinafter described and claimed, it being understood that changes in the precise embodiment of the invention herein disclosed may be made within the scope of what is claimed without departing from the spirit of the invention.

BRIEF SUMMARY OF THE INVENTION

[0008] This invention is a HDPE (High Density Polyethylene) Foam Core Laminate Structure with an HLMI-HDPE Surface. The laminate can be formed in sheets, tubes, and/or other shapes. It can be formed and/or thermoformed into structures such as reusable and disposable pallets and/or containers. The invention provides for the use of a laminate structure made with a HDPE foamed sheet as a core with one or two surfaces of a solid or foamed material. This patent gives preference for having one or more high molecular weight HDPE skin surfaces. High molecular weight HDPE gives high impact strength to the skin surface. For the core, a medium molecular weight HDPE with a melt index in the range of 0.2 to 0.4 g/10 min is used to help produce acceptable quality foam and provide the performance characteristics desired. For the skin surfaces, the preference is for the use of a high molecular weight, 10 to 12 g/10 min high load melt index HDPE with desired physical properties. Either or both of the skins can be solid or foamed. Either or both of the core and skin surfaces can be made with neat or crosslinked HDPE. Core thickness and skin thicknesses would be dependent upon end use application. The preferred construction would be to produce the laminate structure by an extrusion process. The foaming of the core, and/or skins, can be done with a physical blowing agent or a physical blowing agent with some chemical blowing agents. Skins will preferably be solid for impact strength. Should the skin or skins not be solid, the foaming of the skin or skins, can be done with physical and/or chemical blowing agents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The character of the invention, however, may best be understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

[0010] Figure 1. is an end view of a HDPE foam core with solid skin laminate construction; preferred total thickness of 0.270" thick with core of 0.210" and 2 skins at 0.030" thick,

[0011] Figure 2. is an end view of HDPE foam laminate construction before being thermoformed into pallet construction,

[0012] Figure 3. is an end view of HDPE foam laminate construction after being thermoformed into pallet construction, and

[0013] Figure 4. is an end view of HDPE foam laminate pipe or tube construction after being extruded.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Polymeric foam structures are known in the art for their use in weight reduction while providing artifacts with acceptable physical property characteristics. Polymeric foam structures are further used to enhance desired characteristics such as shock attenuation, insulation, or buoyancy. It is further known in the art to enhance the physical properties of foam structures by laminating solid or higher density foams together with lower density foams to enhance their physical properties. The laminated construction provides the foam structure with resistance to bending and flexing. The foam laminate structure has greater stiffness, resists creasing, and more effectively dissipates loading forces of the foam. This provides a composition with greater viability for end use applications.

[0015] It is known that polyethylenes are polymeric materials that are characterized by toughness, good chemical resistance, good electrical insulating properties, low coefficient of friction, low moisture absorption, low temperature flexibility, and ease of processing. It is further known that high density polyethylenes are crystalline, very tough materials that have greater stiffness, higher melting point, and improvement in tensile strength over low density

polyethylenes. Given the improvement in the desired properties, the polyolefin of choice for this patent is high density polyethylene [HDPE]. More significant to the novelty of the patent is the use of a low molecular weigh HDPE a greater density reduction of the core segment and the use of a high molecular weight HDPE for the surface.

[0016] Included in this invention, but not limited to, one such end use application is the construction of pallets for material transport. Historically pallets for moving materials such as food products, building supplies, boxes, parts, etc. have been made of wood with hand labor construction. Pallets for the same types of material transport have been made of various plastics produced by injection molding, blow molding, or rotational molding. More recently, pallets have been made of solid constructions of HDPE or high molecular weight HDPE. This invention provides for a laminated foam structure made of HDPE core with skin surface or surfaces and thermoformed as an improvement in the construction of a pallet. This invention prefers the construction of a three part laminate, but is not limited to the same. For example, a two part laminate without one skin surface, or a multi-laminate construction with multiple solid or higher density foam layers between lower density foam core segments are also applicable for this invention. Included in this patent is the concept for a disposable pallet. Given the relative low cost of the HDPE construction materials and with the capability to provide a thinner construction of a pallet for support of cargo materials, the fabrication of a disposable pallet becomes feasible.

[0017] This invention provides for the use of a foam core of an alternate more foamable HDPE with a significant reduction in density with a surface skin or skins of a high molecular weight HDPE to impart the strength and rigidity desired. The layered construction provides comparable performance characteristics as the solid construction but with a significant reduction in weight. The significant weight reduction has a positive effect on the ergonometrics of any construction with the material. The laminated structure can then be used as flat sheet construction for insulation, packaging, padding, etc. or thermoformed into a specific shape. As such, this patent also identifies the feasibility for the thermoforming of a pallet, a tote, or other container like construction for material transport or any object or part for non-material handling applications utilizing the laminate construction.

[0018] Another example of similar composition and construction is the fabrication of

industrial totes. The laminate construction permits a weight reduction without unacceptable loss in stiffness and strength. The thermoformable laminate construction provides a reduction in weight, reduction in material and processing costs, and improvement in the ergonomics of the device as a result of the weight reduction.

[0019] An alternate use of this structure is in a tubular construction. That is, in place of the use of a flat extrusion sheet, an annular extrusion die is used to produce a multilayer tube. Dependent upon material composition, density of foam, inside and outside diameters and various other design parameters, this tube can be used to produce assorted cylinder constructions such as bottles or bottle wraps, non-metallic cans, pipe and/or corrugated pipe. In any constructions, whether flat, tubular, or regular or irregular profile, the foam core is made of a foamable HDPE to permit a significant reduction in density while the surface skin or skins are preferred to be of a high molecular weight HDPE to impart the strength and rigidity.

[0020] The preferred materials used for construction of the foam laminate in this patent are various grades of high density polyethylene [HDPE]. The preferred materials include but are not limited to the following. For the foam core a 0.2 to 0.4 g/10 min fractional melt HDPE such as the Fina S-528 or ExxonMobil AA55-003 is preferred which will provide stiffness and improve processing characteristics.

[0021] For the solid skin layer, the preferred material is a high molecular weight, 10 to 12 g/10 min high load melt index HDPE. Examples of this type of resin include but are not limited to: Novacore HB-952 [a HLMI /high load melt index] or ExxonMobil BA50-100 [also a HLMI /high load melt index] for the solid skin layers.

[0022] Dependent upon desired properties and processing, the materials utilized for either the foam core or solid skin or skins or both in this construction can be crosslinked or non-crosslinked.

[0023] The core composition can be varied dependent upon end use application. The preferred core composition will utilize a low melt index, preferably high melt strength medium molecular weight HDPE which will provide an optimal flexural stiffness for

construction yet still provide processability for foaming the material. HDPE is available in various densities and melt indexes. The HDPE core material will preferably be a high melt strength, medium molecular weight HDPE with a density to provide stiffness.

[0024] However, the grade must be commercially available and also a grade of HDPE that can be foamed. The preferred HDPE will permit the lowering of the foam apparent density by either physical or physical and some chemical blowing agents. Physical blowing agents for use include but are not limited to organic materials as hydrocarbons or chlorinated hydrocarbons, or inorganic materials as nitrogen or carbon dioxide or combinations of both. Chemical blowing agents can be of the exothermic or endothermic types. For this patent, the preferred blowing agent use is carbon dioxide with an endothermic chemical blowing agent.

[0025] The density range of the resultant foamed core can vary from 20.0 PCF to 58 PCF, more preferably from 30.0 to 40.0 PCF, and most preferably 35.0 PCF. The foam density can be raised or lowered to meet physical property requirements of the end use. A greater load-bearing requirement of the final end product will predicate a higher density foam core.

[0026] For a pallet application the preferred thickness of the foam core can be from 0.100" to 1.0" thick, for preferably from 0.200" to 0.500" thick, and more preferably from 0.200" to 0.300" thick. The end use application and ease in processing; foaming and post laminating processing and/or thermoforming will predicate foam core thickness.

[0027] The skin composition will also be dependent upon end use application. The preferred skin composition will utilize a 10 to 12 g/10 min high load melt index HDPE to impart stiffness and resistance to bending to the laminate construction. Dependent upon end use application, if other polymers are used, whether as an alloy or a multi-layer laminate construction, the desired goal of additional stiffness from the laminate construction will be the guiding principle for construction. The skin is preferred to be solid material. However, dependent upon end use application, this invention permits the skin to be foamed with a density range from 20 PCF to 60 PCF. The thickness of the skin will depend upon end use of the application. The range of the skin can vary from 0.001" to 1.00" thick. The preferred range of skin thickness will be from 0.010" to 0.100" thick.

[0028] Dependent upon desired end use, additives including but not limited to anti-static, conductive, colorants, antioxidants, UV inhibitors can be added to either the foam core or either or both skins. Similarly, should the application warrant, an additional layer can be added to or as an alternate to the skin or skins, of either a solid or foamed material. The subsequent additional layer can be, but may not necessarily be made of HDPE, dependent upon the application. Alternate materials including but not limited to, LDPE, CPE, PP, ESI, ionic polymers, fabrics, non-woven materials, etc. can be used to impart improved properties to the skin such as: improved adhesion, improved fire retardancy, conductivity, UV protection, color, texture, softness, gloss or matte finish, etc.

[0029] Several methods for the construction of the foam laminate structure are possible within the scope of this patent. One feasible process includes an extrusion process for foaming utilizing physical blowing agent(s) or physical and some chemical blowing agents with a subsequent film or extruded sheet calendered directly to the foam core. An alternate method could utilize a multilayered calendered sheet with a high temperature chemical foaming agent for subsequent foaming. The preferred method for construction of the laminate structure is a multi-layer extrusion process. The core layer foamed with physical blowing agent(s) and the skin layers will simultaneously be extruded and laminated by the extruder/die configuration.

[0030] The thickness of the over all laminate structure will depend upon the final end use application. The desired capabilities of the laminate structure are related to their performance characteristics. For example, highly sensitive electronic or military apparatus may require a thicker foam core whereas materials with a low sensitivity to shock would require a thinner construction. For the end use application of a pallet, the thickness of the foam laminate structure could range from 0.150" to 22.00" thick. The preferred thickness of the laminate construction will range from 0.100" to 2.00" thick. The more preferred thickness of the laminate construction will range from 0.200" to 0.400" thick.

[0031] This invention also identifies a thermoforming process for pallet construction, tote or box forming, packaging insert, or any construction for holding, moving or conveying materials with the said construction. The foam laminate composition is subjected to a secondary thermoforming operation. This secondary operation can be in line or off line to

the foaming/laminating composition process. The material composition of the foam/skin laminate is chosen to permit the subsequent forming of the laminate without foam collapse nor distortion of foam and/or solid components.

[0032] This patent, however, does not limit the use of the construction to only packaging or dunnage applications, but permits any use of the construction where a rigid light laminate construction is preferable for use. Examples of potential non-packaging use include but are not limited to: boat, canoe or kayak, travel trailer, recreational vehicle and mobile home construction, truck liner, truck trailer roofing, cabinet making, sports equipment, and automotive applications.

[0033] Further this patent does not restrict the construction to a three layer composition, but dependent upon application and choice of materials, there can be two, three, four, five, or greater number of layers in the construction. Similarly dependent upon application, each layer can be a designated thickness different than or equal to the thickness of any other layer. Additionally, material choice for each layer can be the same or different dependent upon desired property or attribute for improvement in the composite structure. Example of improve properties or attributes include but are not limited to color, UV resistance, cold impact performance, softness, feel or hand, conductivity, chemical resistance, etc.

[0034] Choice of resin for foam core is dependent upon material property requirements, including but not limited to impact strength and stiffness. Either or both of the skin surfaces can be made of a fractional melt HDPE or high molecular weight HDPE or blends of either dependent upon material property requirements. The HDPE skins are preferred to be from 0.005" to 0.080", more preferred 0.030" to 0.070". For applications that require greater impact strength, use the high molecular weight in both the foam core and in the skins. For applications that do not require greater impact strength, the use of a fractional melt more foamable grade HDPE in both the foam core and skins is preferred. An example for the use of this construction is the disposable pallet which has less stringent physical property requirements but need for lower cost construction. The foam or foam core with one or more skins constructions can be made in a sheet, tubular, or profile construction. The foam or foam core structure can be flat or corrugated sheet construction. The foam core structure can be blown to a 25% to 60% reduction in density, preferred a 40% to 60% reduction in

density. A tubular foam or foam core with one or more skins construction can be made with either or both of the skin surfaces can be made of a fractional melt HDPE or high molecular weight HDPE or blends of either dependent upon material property requirements. A tubular foam or foam core with one or more skins construction can be used to produce large diameter, straight walled or corrugated walled, pipe. The advantage to its use in this pipe is a weight savings and subsequent lower cost and ease of use. An application such as this is in large diameter irrigation pipe which has lower weight to help facilitate its use in moving. The foam or foam core or foam core and skin or skins can include the addition of additives such as antioxidants, UV inhibitors, heat stabilizers, etc. for desired material characteristics. Thermoforming of reusable and/or lightweight disposable pallets with the foam or foam core structure can reduce thermoforming cycle time by 25% to 30%. A skin or the skins of two sides can be made of the same or different HDPE [high molecular weight or the fractional melt material] and used to construct pallets dependent upon the end requirement. That is, fractional melt HDPE could be used for both the foam core and skins should a cheaper disposable type pallet be desired, when lower impact resistance is acceptable. However, high molecular weight HDPE could be used when greater impact strength is required as in a reusable pallet.

[0035] Figure 1. is an end view of a laminate 10 embodying the principles of the present invention, having a HDPE foam core 11 with solid skin laminate construction. There is an upper skin 12 and a lower skin 13. The laminate has a preferred total thickness of 0.270", with core of 0.210" and 2 skins at 0.030" each. Figure 2. is an end view of HDPE foam laminate construction before being thermoformed into pallet construction. The thermoforming die 14 is shown. Figure 3. is an end view of HDPE foam laminate construction after being thermoformed into pallet construction. The legs 16 and 17 are formed of the localized melding of the skins 12 and 13, and the crushed foam 11. The legs 16 and 17, support the deck 15.

[0036] Figure 4. is an end view of HDPE foam laminate pipe 20 or tube construction after being extruded. The foam 21 has an outer skin 23, and an inner skin 22.

[0037] It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to

confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

[0038] The invention having been thus described, what is claimed as new and desire to secure by Letters Patent is:

What is claimed is:

CLAIMS

1. An invention for a HDPE foam core composition structure, in which the HDPE foam core is made of a fractional melt HDPE, or high molecular weight HDPE or blends of either.

2. Preferable use of 0.1 to 0.5 g/10 min. melt index foamable grade of HDPE for a producing the foam core of claim 1.

3. Use of a high molecular weight, higher melt index, stiffer grade of HDPE for skin surface or surfaces of the HDPE foam core composition structure in claim 1.

4. Use of a physical foaming agent or agents or physical and some chemical foaming agent or agents, or both or combinations or either to produce a HDPE foam core of claim 2.

5. When not as a solid surface, use of a physical foaming agent or agents or physical and some chemical foaming agent or agents, or both or combinations or either to foam the skin or skins of claim 3.

6. Use of a HDPE resin with a high load melt index to produce a skin surface.

7. Use of same, thought the preferred is a different, HDPE for both the core and the skin surface(s).

8. Use of dual or three layer extrusion process, or an extrusion process in line to produce a construction and/or a downstream extrusion coating process, and/or a lamination process to a foam core or foam core/skin structure to produce a foam or foam/solid laminate construction.

9. Use of a calendar process to produce a foam laminate construction.

10. Use of a two, three, four or more layer extrusion process to produce a foam or foam/solid laminate construction.

11. Use of a two, three, four or more layer extrusion process and a subsequent calendar process to produce a foam or foam/solid laminate construction.

12. Use of a thermoforming process to produce a desired shape end product.

13. Construction of a pallet, tote, or material handling container with a foam core composition utilizing a thermoforming process.

14. Construction of a corrugated pipe with a foam core composition.

15. Construction of part or device where a foam core composition will provide an improved attribute in place of the use of a solid construction for the same requirement.

16. Choice of resin for foam core is dependent upon material property requirements, including but not limited to impact strength and stiffness.

17. Either or both of the skin surfaces can be made of a fractional melt HDPE or high molecular weight HDPE or blends of either dependent upon material property requirements.

18. The HDPE skins are preferred to be from 0.005" to 0.080", more preferred 0.030" to 0.070".

19. For applications that require greater impact strength, use the high molecular weight in both the foam core and in the skins.

20. For applications that do not require greater impact strength, the use of a fractional melt more foamable grade HDPE in both the foam core and skins is preferred.

21. An example for the use of this construction is the disposable pallet which has less stringent physical property requirements but need for lower cost construction.

22. The foam or foam core with one or more skins constructions can be made in a sheet, tubular, or profile construction.

23. The foam or foam core structure can be flat or corrugated sheet construction.

24. The foam core structure can be blown to a 25% to 60% reduction in density, preferred a 40% to 60% reduction in density.

25. A tubular foam or foam core with one or more skins construction can be made with either or both of the skin surfaces can be made of a fractional melt HDPE or high molecular weight HDPE or blends of either dependent upon material property requirements.

26. A tubular foam or foam core with one or more skins construction can be used to produce large diameter, straight walled or corrugated walled, pipe.

27. The advantage to its use in this pipe is a weight savings and subsequent lower cost and ease of use.

28. An application such as this is in large diameter irrigation pipe which has lower weight to help facilitate its use in moving.

29. The foam or foam core or foam core and skin or skins can include the addition of additives such as antioxidants, UV inhibitors, heat stabilizers, etc. for desired material characteristics.

30. Thermoforming of reusable and/or lightweight disposable pallets with the foam or foam core structure can reduce thermoforming cycle time by 25% to 30%.

31. A skin or the skins of two sides can be made of the same or different HDPE [high

molecular weight or the fractional melt material] and used to construct pallets dependent upon the end requirement.

32. That is, fractional melt HDPE could be used for both the foam core and skins should a cheaper disposable type pallet be desired, when lower impact resistance is acceptable.

33. High molecular weight HDPE could be used when greater impact strength is required as in a reusable pallet.

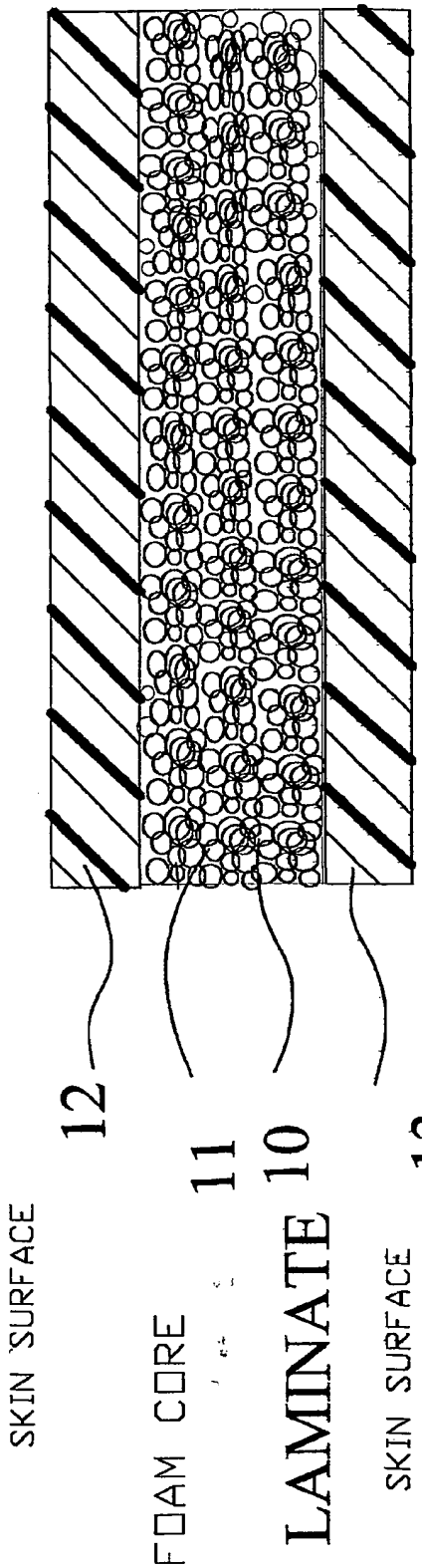

FIG. 1

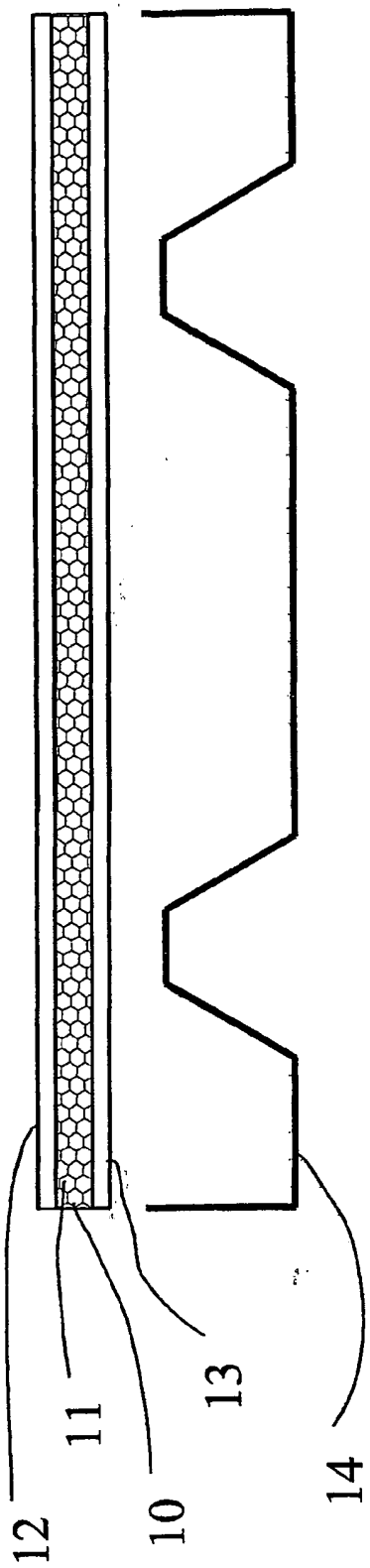

FIG. 2

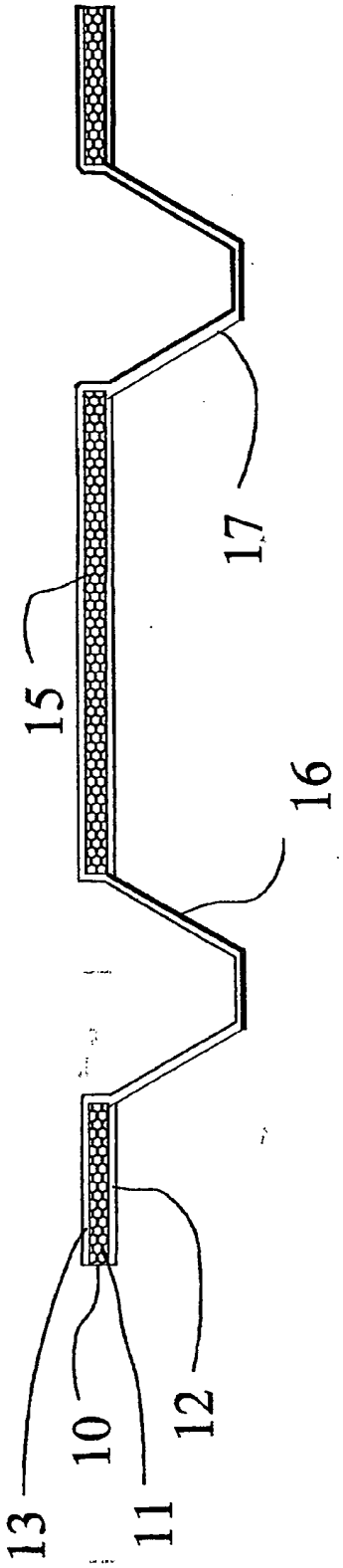

FIG. 3

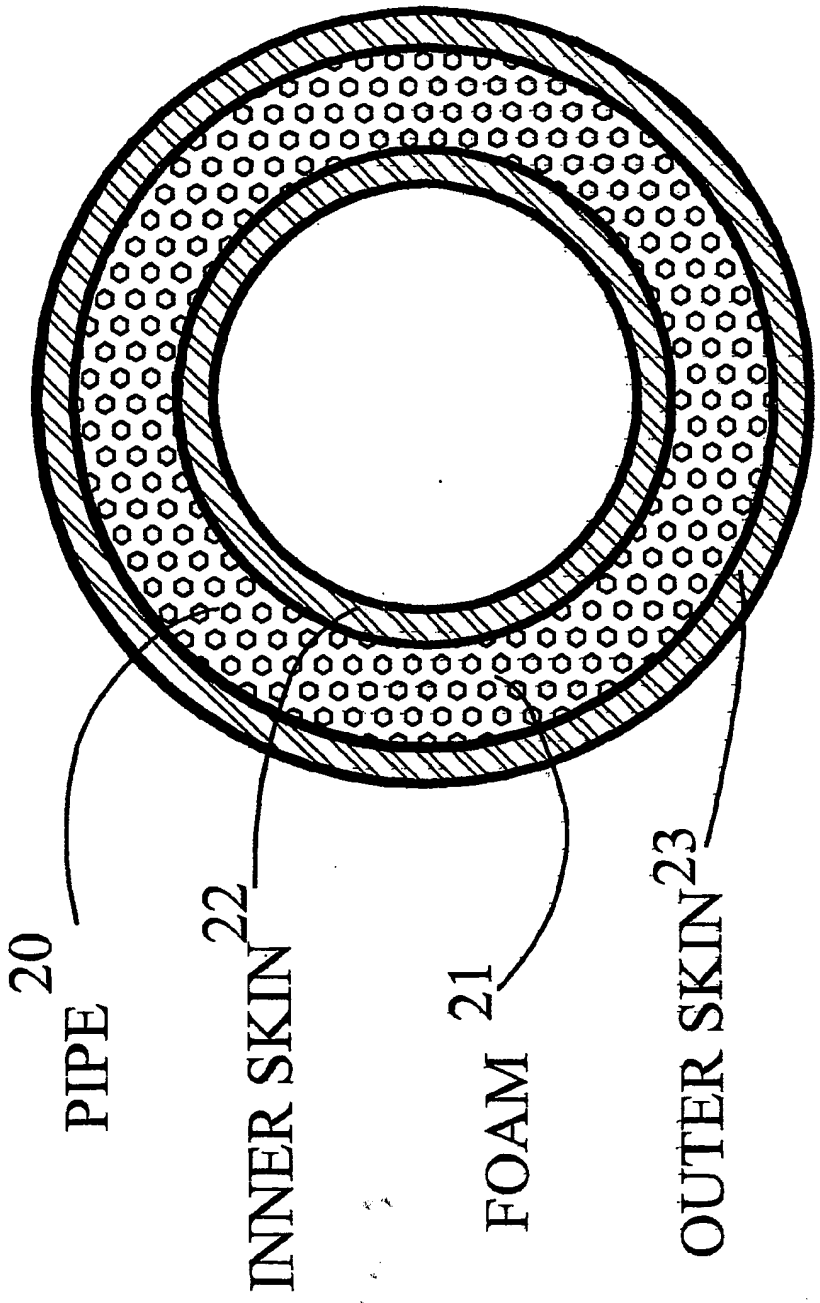

FIG. 4